Tropospheric Ozone Profiling Using Simulated GEO-CAPE Measurements

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GEO-CAPE COMMUNITY WORKSHOP

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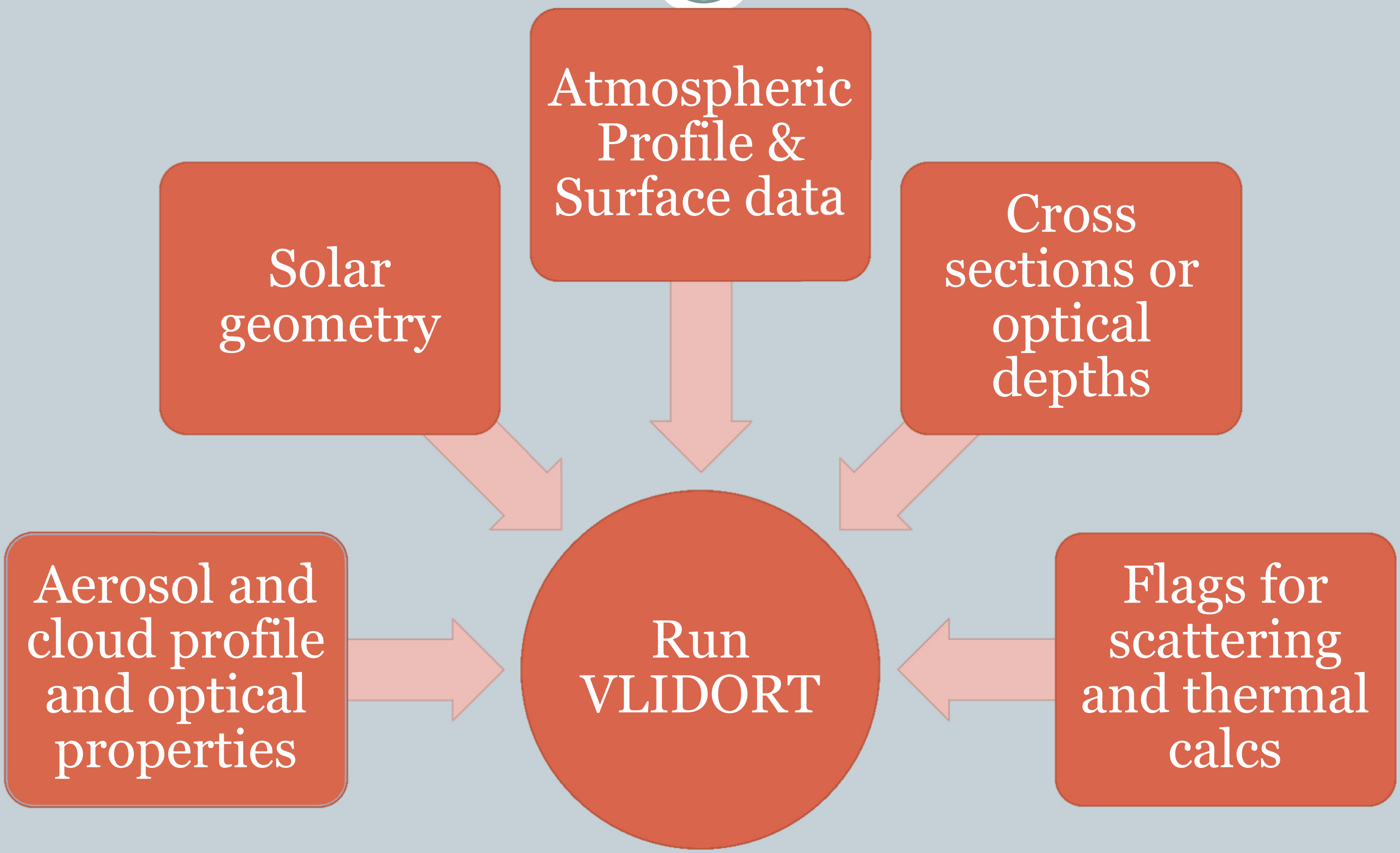
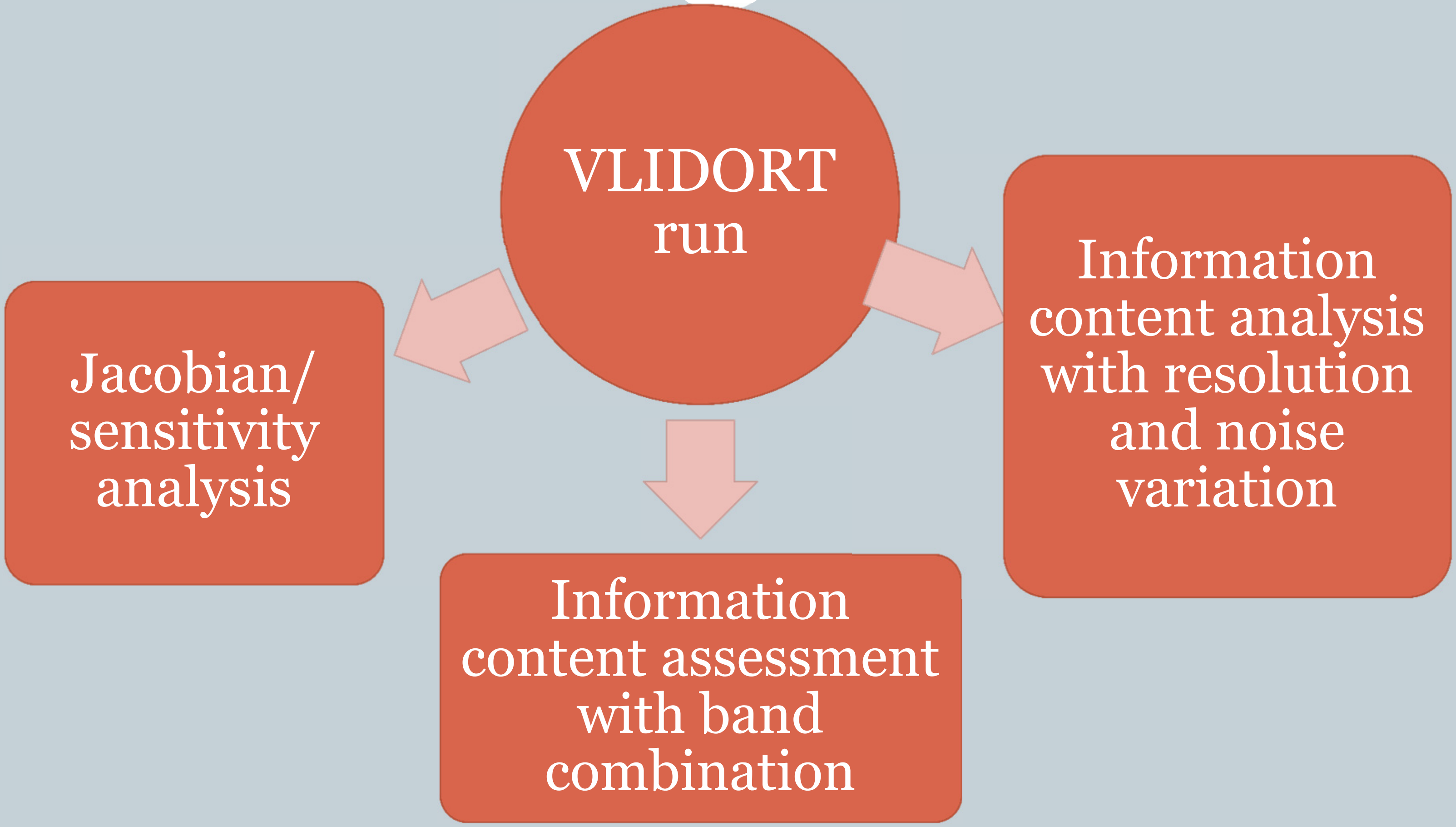
Goals

- Rationale: Measurement requirements in GEO-CAPE STM go beyond current demonstrated capability
- Focus: Assess sensitivity (to amounts and vertical distribution) of trace gas retrievals to wavelength set used
  - Can needed vertical sensitivity be achieved with new combinations of wavelengths?
- Method: Radiative transfer simulations and Jacobian analysis (focus on ozone)

VLIDORT – Part 1



VLIDORT – Part 2



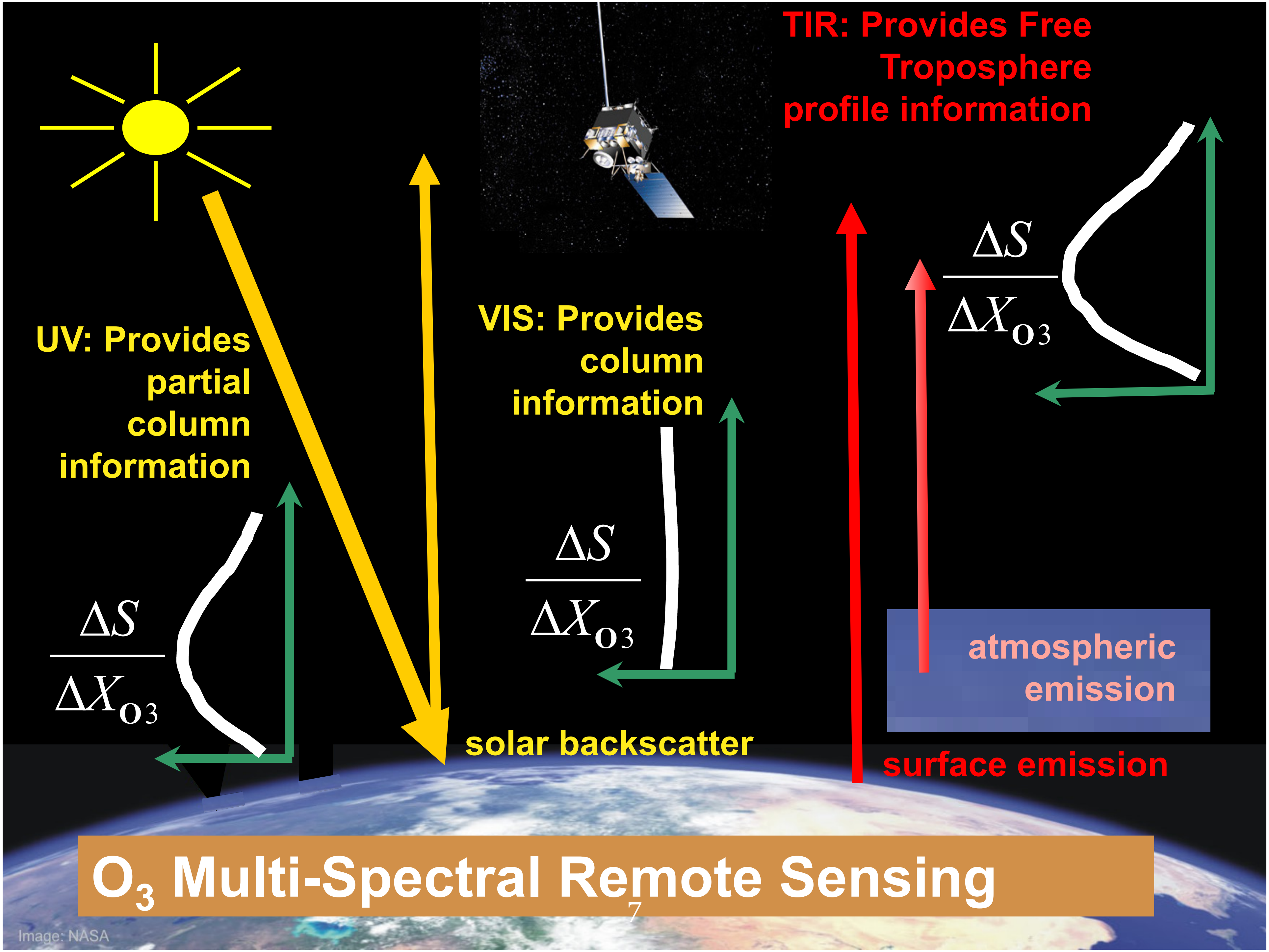
Outline of Results

- Spectral regions used
- O_3, T, H_2O profiles
- DFS summary
- Details for high and low sensitivity cases
- First look at results with aerosols
- Conclusions

Spectral Regions

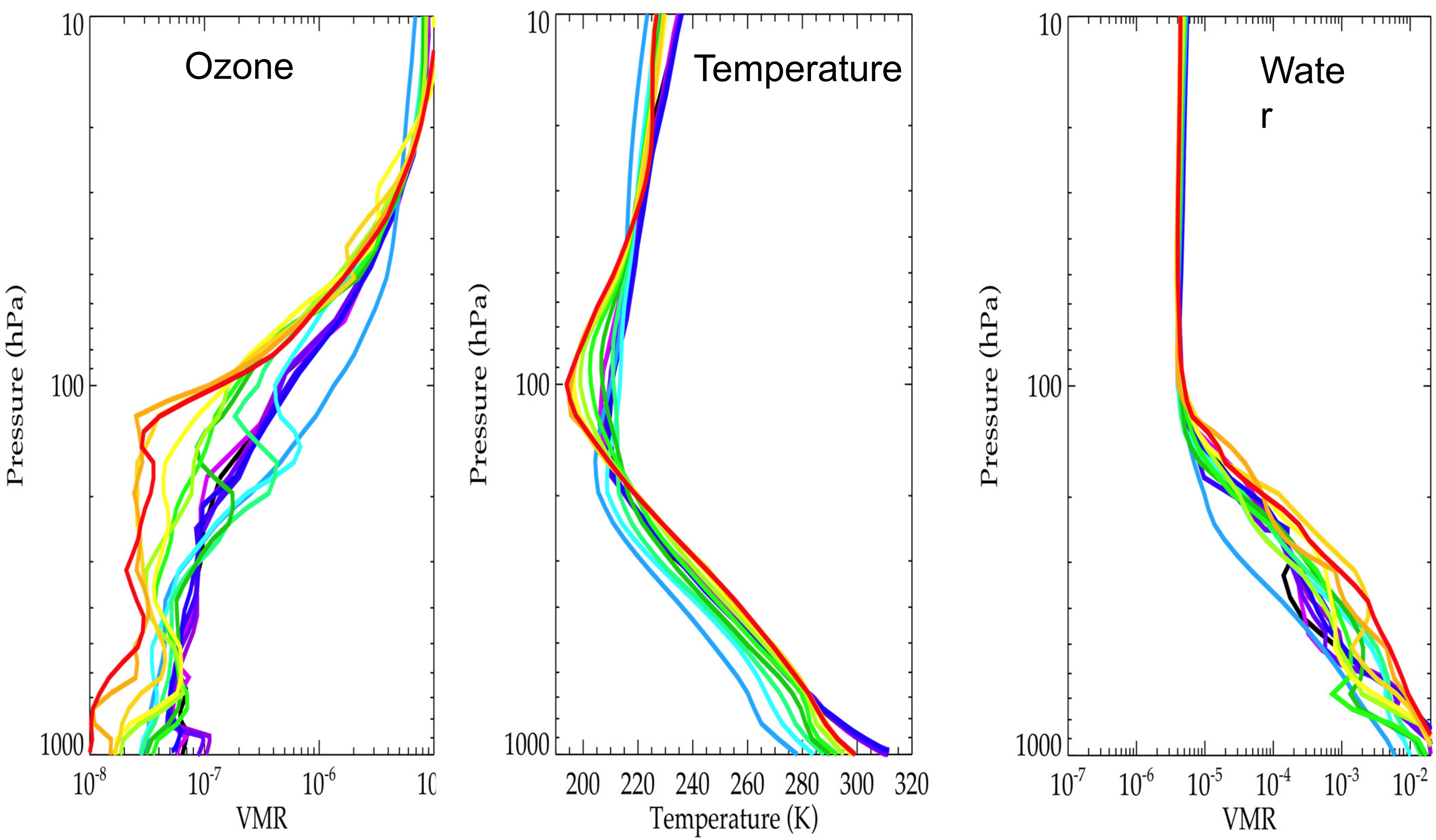
	UV/UVQ	VIS	MIR	TIR
Wavelength	290-340 nm	560-620 nm	3035-3055cm^{-1} 2780-2833cm^{-1}	980-1070 cm^{-1}
Spectral Resolution	0.4 nm	0.4 nm	0.18 cm^{-1}	0.1 cm^{-1}
Spectral Interval	0.1 nm	0.1 nm	0.0275 cm^{-1}	0.06 cm^{-1}
Signal to Noise Ratio	3 times of OMI	3 times of OMI	TIMS group 6×6 km^2 10s	3 times of TES

UVQ denotes polarized radiation



O_3 Multi-Spectral Remote Sensing

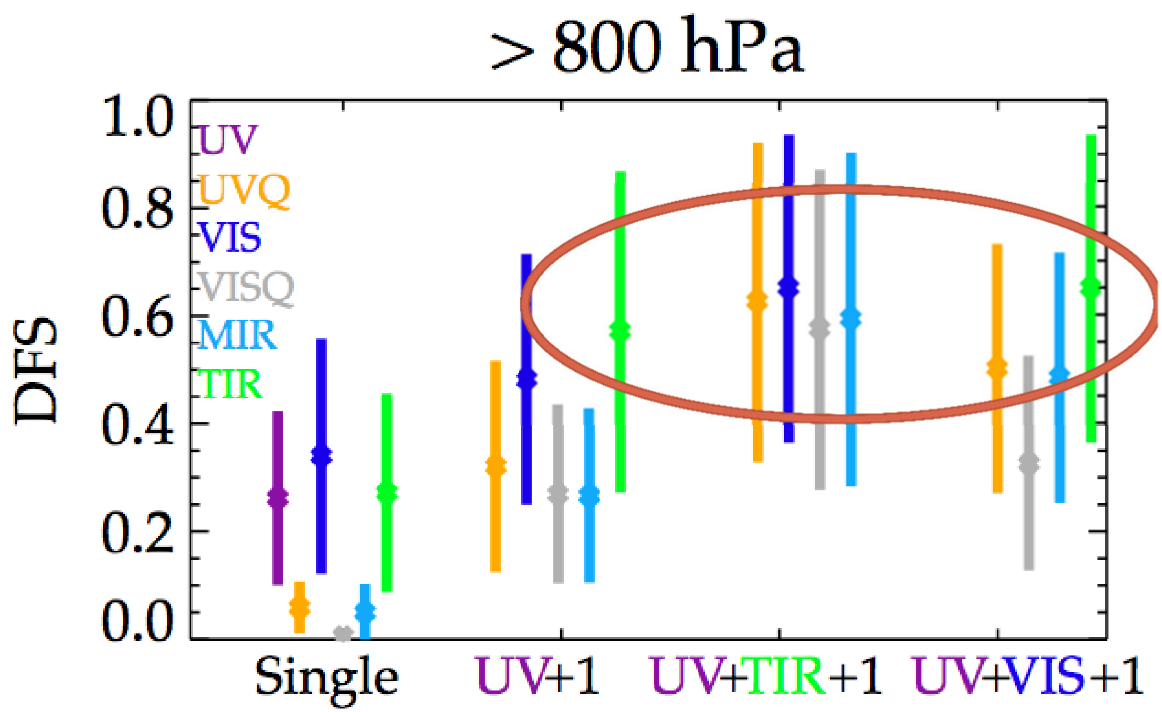
Profile Characteristics



DFS

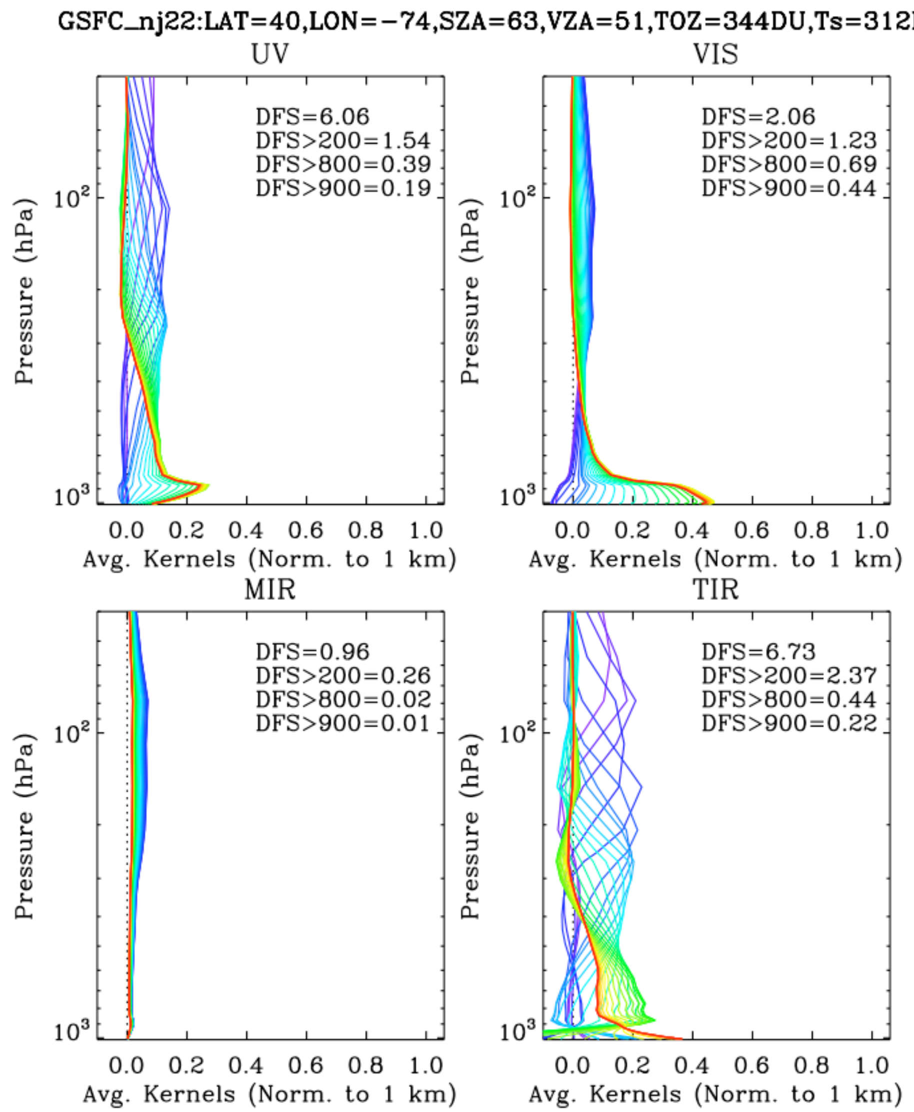
Clearly, there is a group that provides an improvement of sensitivity in the lowest layers

Note: use of Lambertian surface may underestimate power of polarized measurements.



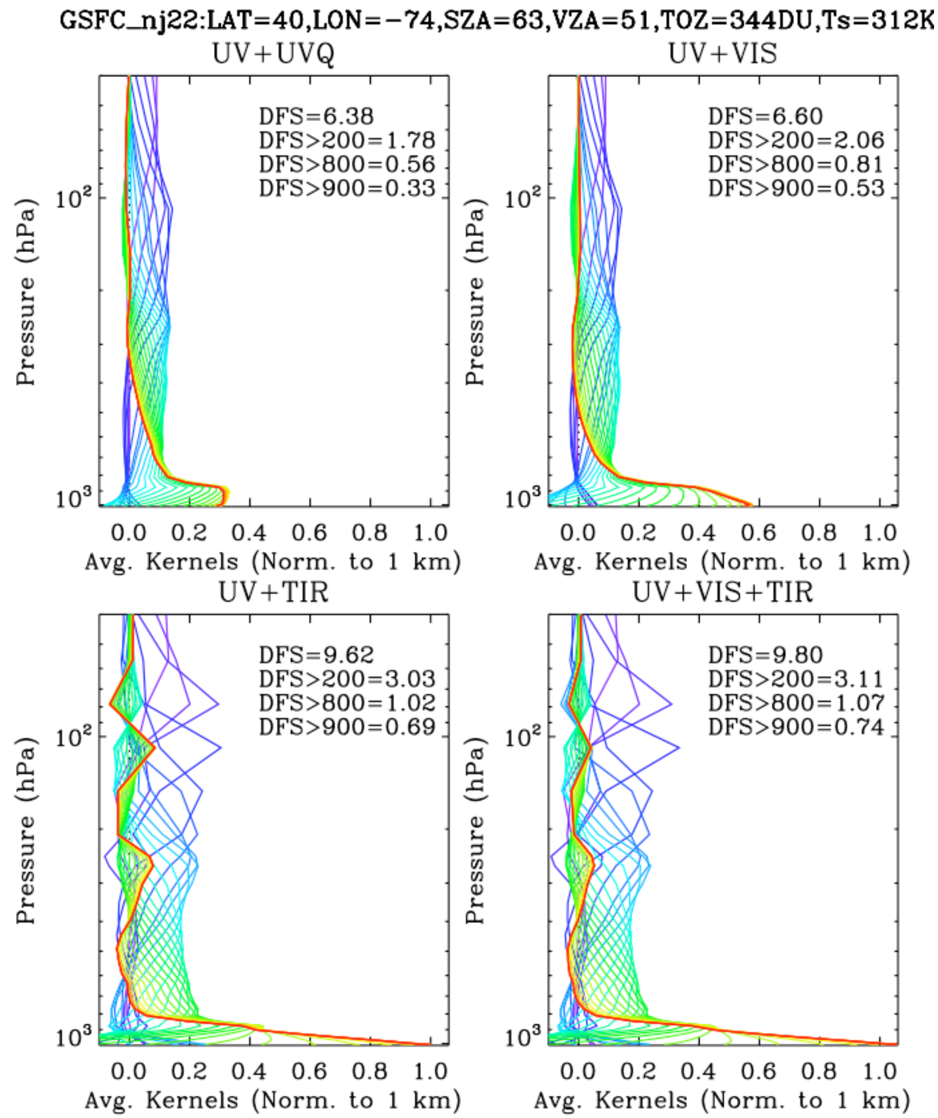
Polluted atmosphere, single band

This profile showed strong sensitivity, it is a polluted atmosphere with an enhanced ozone layer of 80-100 ppbv below 900 hPa



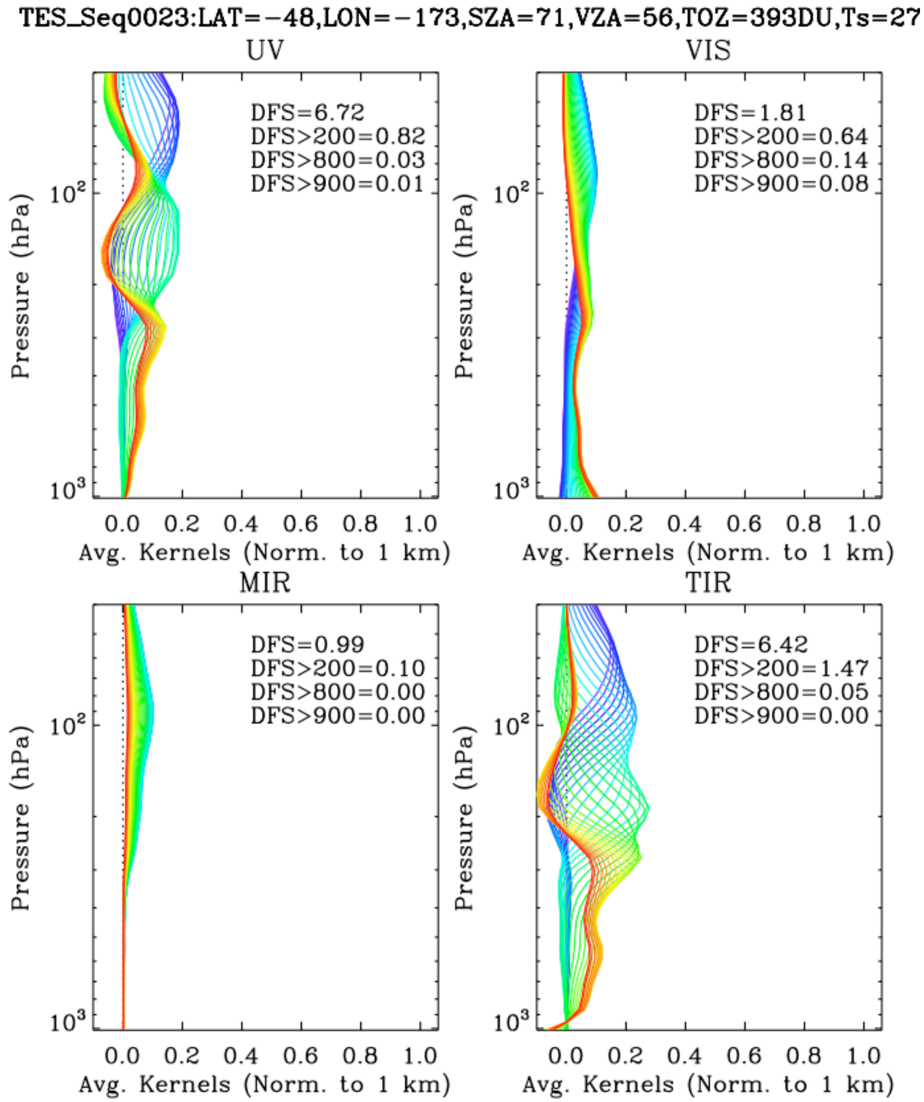
Polluted atmosphere, joint bands

Use of TIR really lets you separate lower layers above and beyond UV+VIS



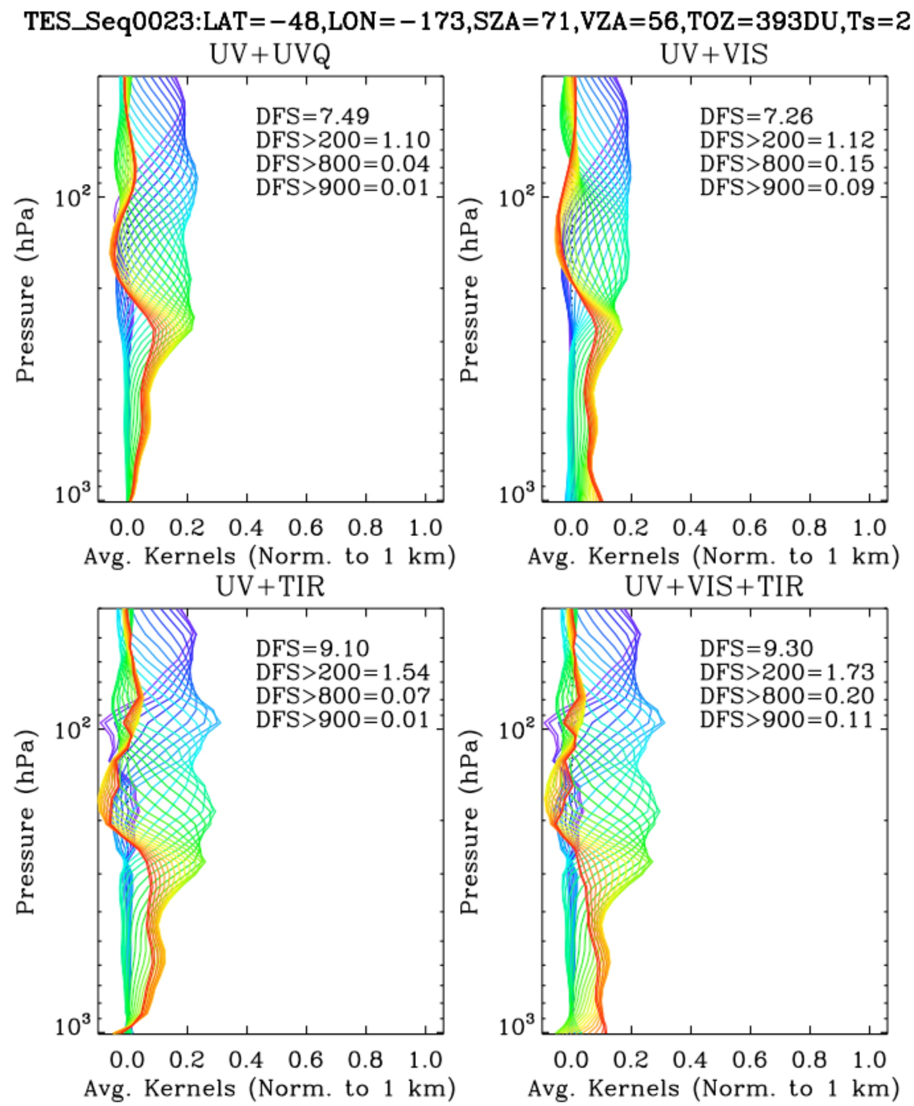
Nominal atmosphere, single bands

This atmosphere features high sza, low temperature and thermal contrast, small a priori variability (clean).

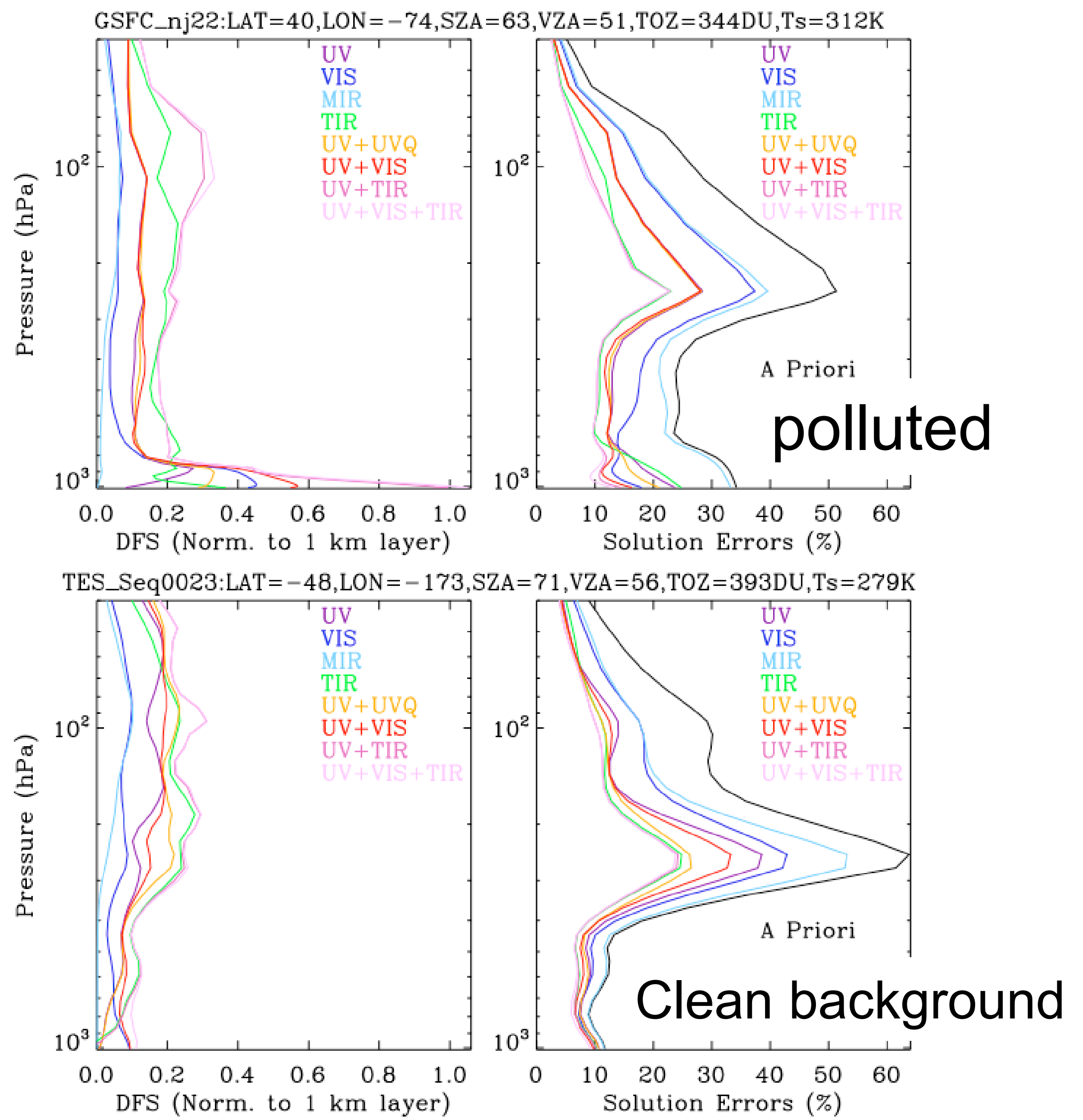


Nominal atmosphere, joint bands

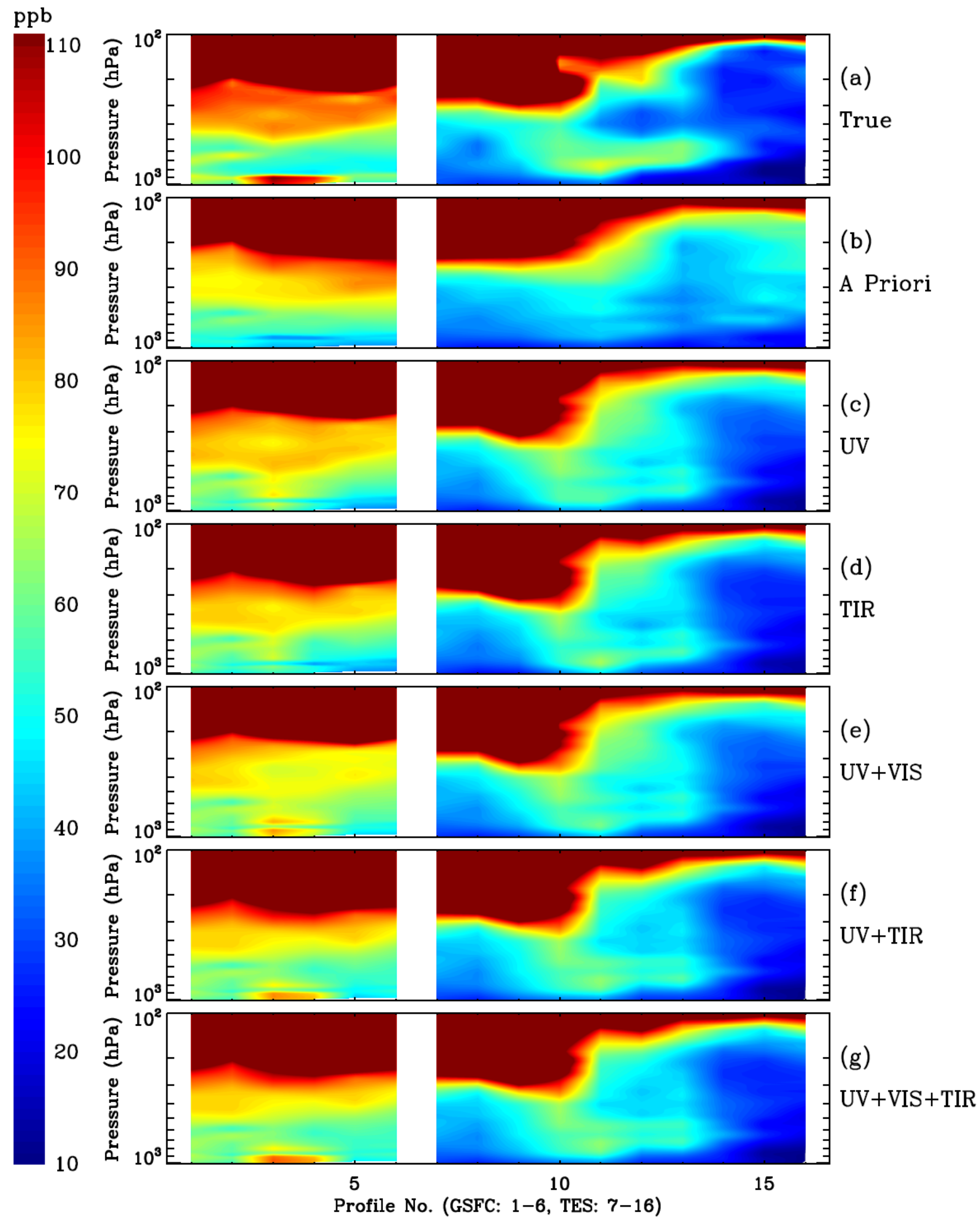
Less dramatic change, but there is increased sensitivity in lower layers



Reduction in Errors



Another Perspective

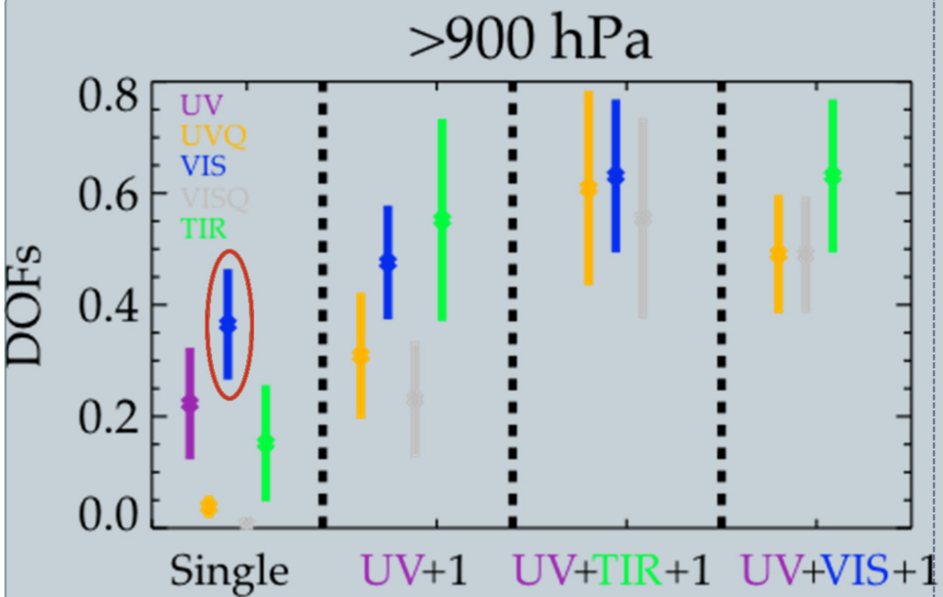


Aerosols: Profiles and Properties

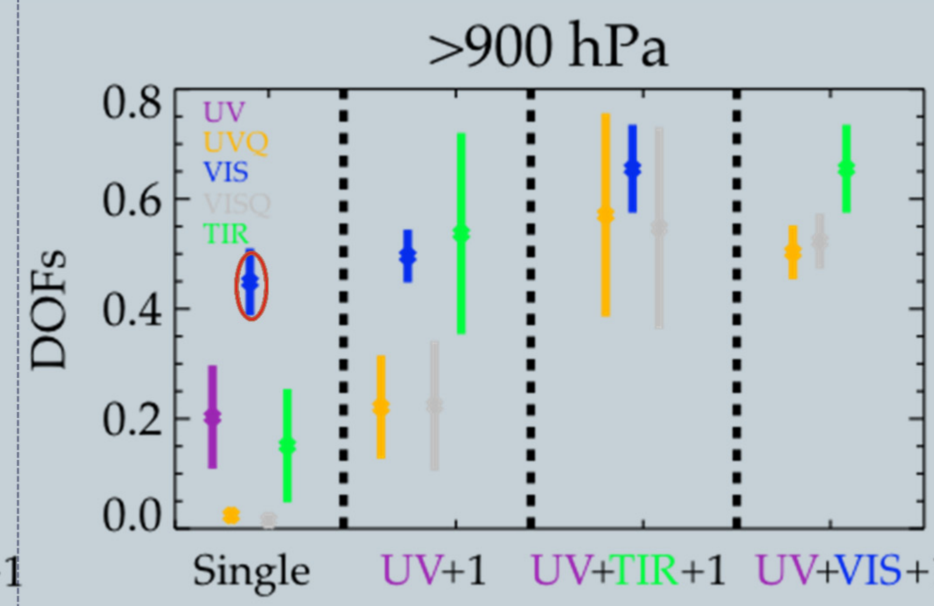
- 5 aerosol types: black carbon, organic carbon, coarse seasalt, fine seasalt, sulfate
- AOD profiles at 300 nm, 400nm, 600 nm and 999 nm (Courtesy: Ken Pickering)
- MODIS total column AOD at 550 nm (Courtesy: Omar Torres)
- RH profiles (Courtesy: Melanie Follette-Cook)
- Only lowest 26 layers have aerosols => no stratospheric aerosols
- Single scattering properties

Aerosols: First Results

Clear Sky



Aerosols



Conclusions

- Multi-spectral retrievals (UV+VIS, UV+TIR, UV+VIS+TIR) improve sensitivity to the variability in near-surface O_3 by a factor of 2-2.7 over those from UV or TIR alone.

- Multi-spectral retrievals provide the largest benefit when there is enhanced O_3 near the surface.

- Combining all 3 wavelengths (UV+VIS+TIR) provides the greatest sensitivity below 850 hPa, with a 36% improvement over UV+VIS and a 17% improvement over UV+TIR.

- The impacts of clouds and aerosols are being assessed.

Conclusions

- To link our results to the STM, OSSEs needed to quantify impact of different observation scenarios
- We will characterize sensitivity and errors as a function of thermal contrast, SZA, VZA, ozone concentrations, surface characteristics, aerosol amounts, etc.
- This tool will allow our work to be directly used for OSSE studies.

Backup Slides

Key Characteristics

% is assumed for VIS and MIR, respectively.

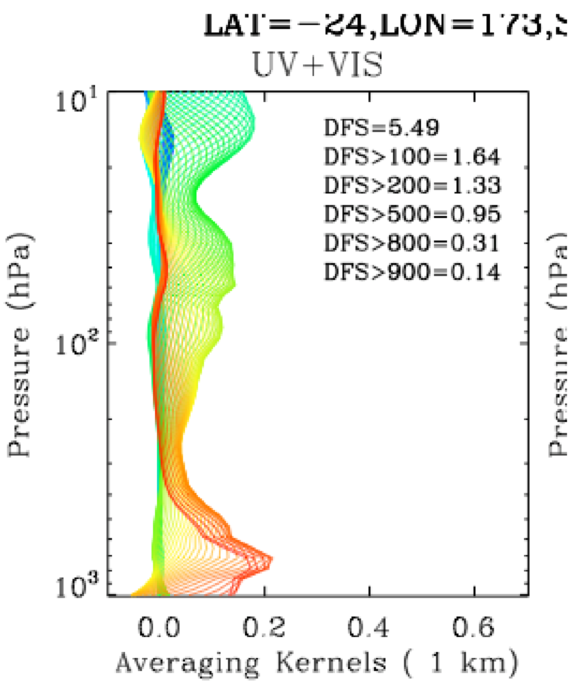
Profile Name	Lat	SZA	VZA	T_s K	T_{contr} K	TOZ DU	TOC DU	$O_{3,bnd}$ ppbv	$\alpha_{s,uv}$	$\alpha_{s,ir}$	H_2O g cm^{-2}
GSFC_nc18	36	17	46	315	0.9	353	47	67.0	0.098	0.016	4.1
GSFC_nc22	36	63	46	307	-5.7	351	44	61.5	0.098	0.016	4.0
GSFC_nj18	40	22	51	312	-0.7	345	49	108.4	0.068	0.026	3.2
GSFC_nj22	40	64	51	306	-6.3	345	47	94.3	0.068	0.026	3.1
GSFC_ny18	44	24	54	308	-3.5	350	41	58.4	0.031	0.019	3.7
GSFC_ny22	43	64	54	303	-8.2	348	39	57.4	0.031	0.019	3.7
TES_Seq0023	-49	71	56	276	-3.4	393	32	31.4	0.058	0.012	0.9
TES_Seq0025	-39	62	46	286	0.6	317	31	28.4	0.089	0.012	2.0
TES_Seq0026	-34	58	41	284	-5.0	306	38	29.5	0.093	0.028	2.6
TES_Seq0027	-30	54	36	299	7.5	298	41	33.1	0.077	0.021	2.0
TES_Seq0028	-25	50	31	312	18.7	286	33	37.7	0.059	0.019	2.0
TES_Seq0029	-20	46	28	302	6.9	264	27	19.3	0.087	0.014	3.0
TES_Seq0030	-15	43	24	297	-1.6	264	26	17.2	0.075	0.012	3.4
TES_Seq0031	-10	39	22	298	-0.4	266	19	17.2	0.092	0.012	3.8
TES_Seq0033	0	33	22	298	-0.8	273	14	15.2	0.077	0.012	4.3
TES_Seq0034	5	31	24	298	-1.2	274	12	10.3	0.092	0.012	4.8

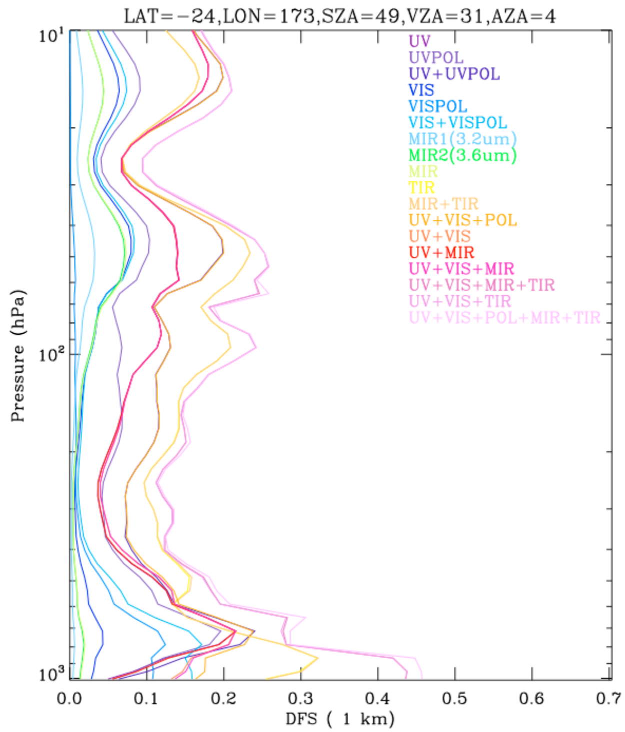
Other inputs

- A priori error: McPeters climatology [McPeters et al., 2007]
- A priori covariance Matrix: correlation length of 6 km
- State vector: ozone at each layer, water vapor at each layer (except for UV), 1 surface albedo/emissivity for each spectral region.
- A priori error for H_2O: 20% at each layer
- A priori error for surface albedo/emissivity: 0.05

Example Analysis

Detailed analysis performed for each of the 16 profiles. We began by looking at every possible combination of the wavelength regions.





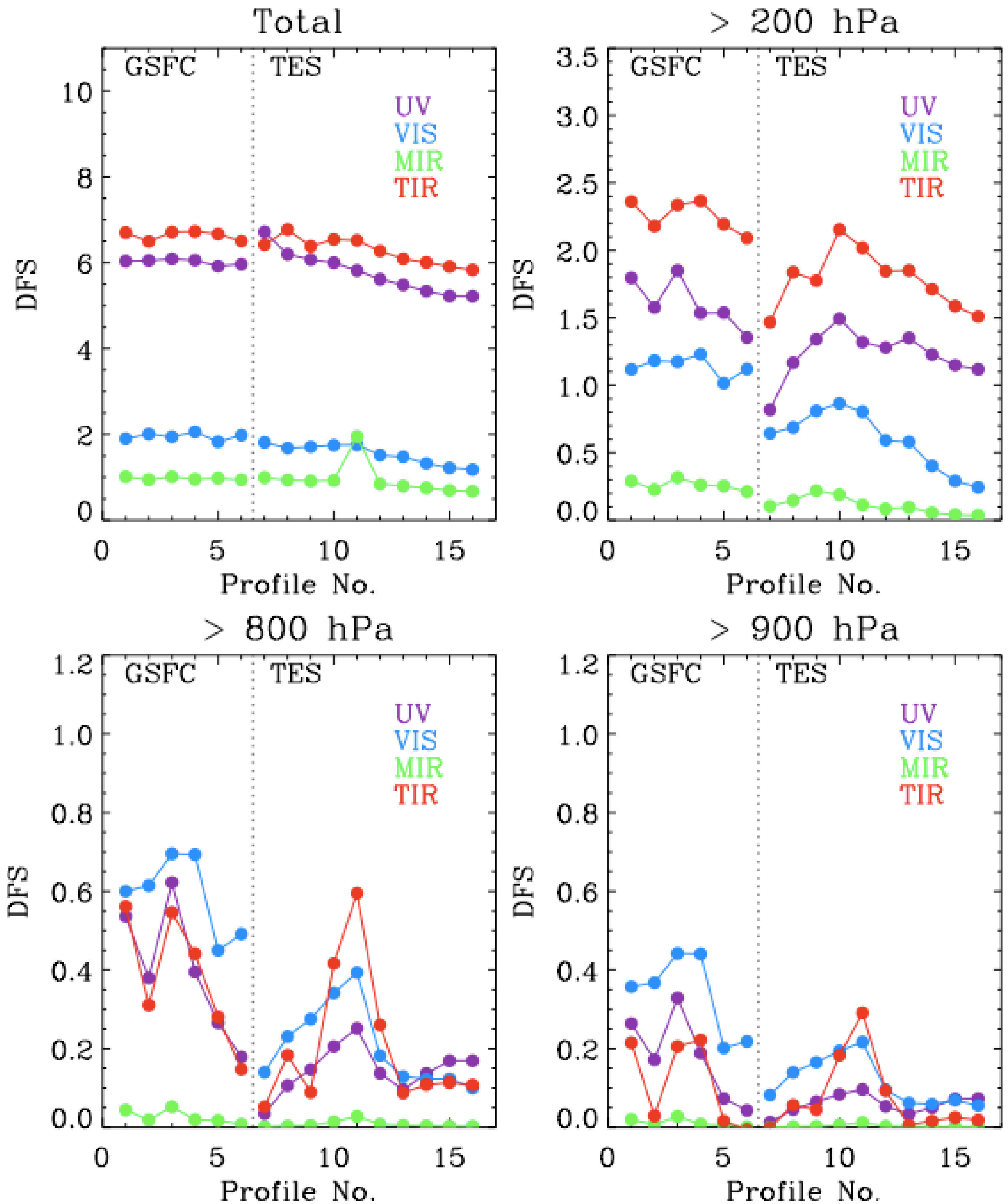
DFS – degrees of freedom for signal – how much information comes from the measurement (as opposed to the *a priori*)

A summary of the DFS for ozone: all possible combos

	Total	>200hPa	>800hPa	>900hPa
OMI	4.68	1.02	0.16	0.06
TES	4.83	1.52	0.17	0.05
UV	5.89	1.39	0.26	0.12
UVQ	4.64	0.76	0.05	0.01
VIS	1.69	0.79	0.34	0.19
VISQ	1.02	0.16	0.01	0.00
MIR	1.28	0.30	0.05	0.02
TIR	6.41	1.96	0.27	0.09
UV+UVQ	6.54	1.63	0.32	0.16
UV+VIS	6.22	1.71	0.48	0.28
UV+MIR	6.01	1.42	0.26	0.12
UV+TIR	8.76	2.45	0.57	0.32
UV+VIS+UVQ	6.79	1.87	0.50	0.29
UV+VIS+TIR	8.90	2.56	0.65	0.38
UV+VIS+TIR+UVQ	9.12	2.63	0.68	0.41
UV+VIS+TIR+UVQ+VISQ+MIR	9.25	2.70	0.71	0.42

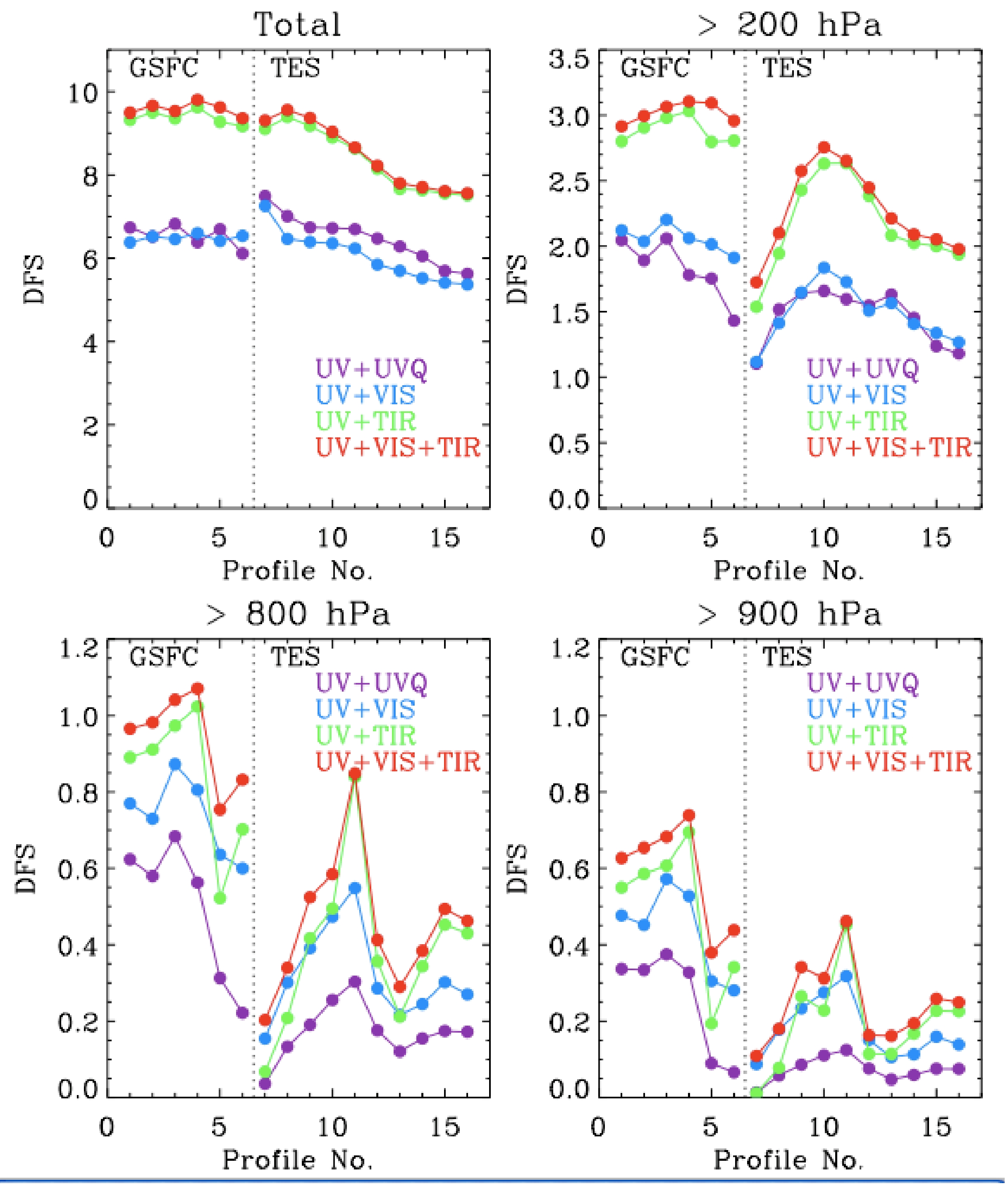
Single

Limited DFS in lower layers

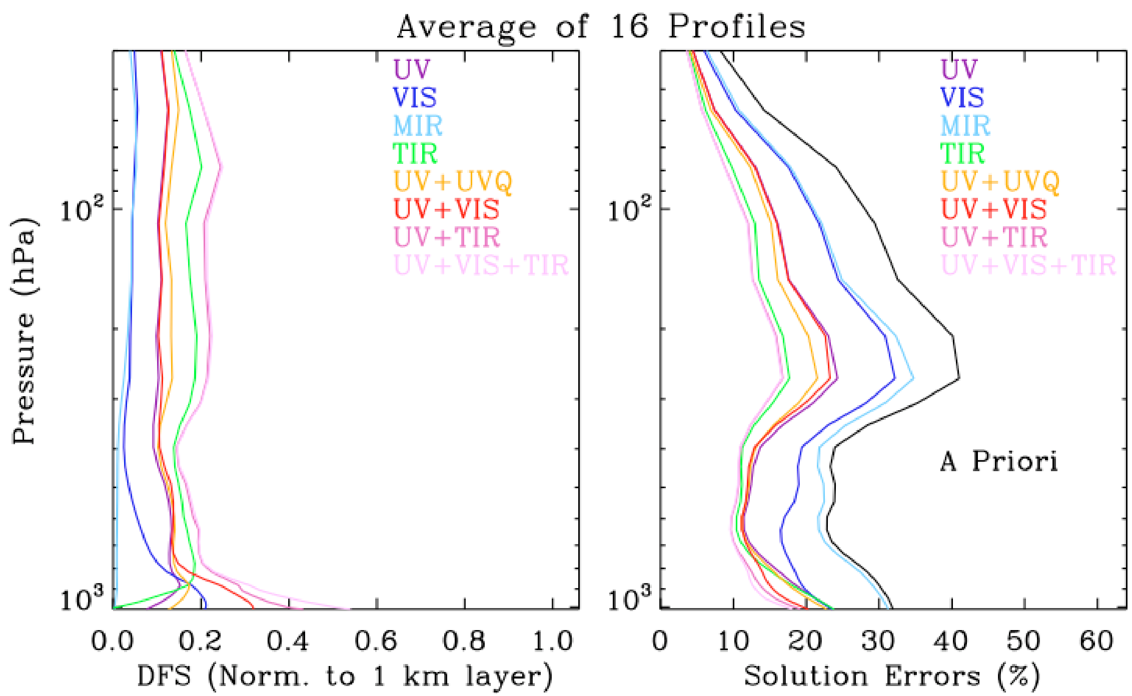


Combined

Significant increase in sensitivity in lowest layers



Vertical Details



Increase noise by factor of 3